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Series Title: AGRICULTURAL MEMORANDUM No 1098

Title: WINTER PROTECTION OF HARDY ORNAMENTAL NURSERY STOCK - 1986/87

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Abstract

Three species of hardy ornamental nursery stock were overwintered in both uncovered beds and beds under low polythene tunnels. The species, chosen to represent a range of winter hardiness, were Rosemarinus officinalis, Spiraea snowmound and Berberis stenophylla.

Temperatures were recorded at 15 minute intervals within the peat based compost in two containers from each treatment. Air temperatures and windspeed were recorded on-site.

Large differences in compost temperatures between the covered and uncovered treatments in the order of 9°C were recorded during a severe weather spell when air temperatures fell to around -13°C. Following snowfall, these differences were reduced to around 2°C.

Despite some of the uncovered treatments recording compost temperatures as low as -10°C at times, winter damage to roots and foliage was not severe, due mainly to the absence of cold, desiccating winds. The covered treatment did, however, produce the most vigorous and forward plants in the spring.

Date : December 1988
Ramp Classification: D2
Key words : Winter Protection; Nursery Stock; Low Tunnels
No of pages : 21
No of diagrams : 5
No of references : 9

FH2B

INTRODUCTION

A study was initiated in December 1986 to determine the effectiveness of several techniques for frost protection of containerised hardy nursery stock.

Air and compost temperatures and wind speeds were recorded on-site. Root death and top growth vigour were assessed on completion of the trial on 3 species:

Rosemarinus officinalis
Spiraea snowmound
Berberis stenophylla

The trial consisted of two components:

Main trial

This was a comparison between several techniques for protecting uncovered pots and pots covered by a low polythene tunnel lined with Agryl (see Annex for details) under clear polythene sheeting.

Supplementary Trial

This was a comparison of different lining materials under a single long tunnel with a polythene outer skin. The tunnel was of similar construction to the above but included specimens of Prunus lusitanica and Berberis stenophylla. However, the Prunus were later found to have suffered from water-logging and were not therefore suitable subjects.

The report is divided into the following sections.

1 Overview of winter weather.

2 Method.

3 Results 3.1 Outside beds vs Blakedown system (main trial) 9-13 Jan 1987
13-16 Jan 1987
29/1-1 Feb 1987

3.2 Multi-covering trial: (supplementary trial) Comparison of compost temperatures: minima

Comparison of compost temperatures: maxima

3.3 Assessment of plant material.

4 Discussion

5 General Conclusions

1 OVERVIEW OF WINTER WEATHER.

For nursery stock, anecdotal evidence suggests that the important meteorological elements governing survival are temperature, windspeed and humidity. Low temperatures alone can directly cause root death (Havis, 1976; Good et al, 1977; Studer et al, 1978) while low temperatures, in combination with low relative humidities and moderate windspeeds, are likely to cause extensive desiccation of foliage. Even if a plant is not killed outright the resulting damage is likely to make it unsaleable.

During a severe winter, national losses of container grown nursery stock can be up to 20%, and in a survey of damage in past years (George, 1986) several were identified to have caused over 10% - see table 1. These same winters were also identified by Barrie (1988) as those having above normal totals of cold, dry winds.

Table 1. Totals of Hours with Dry, Freezing Winds* and Estimate of Winter Damage

	Desiccating Winds (hours)+	Winter Damage (%)
1977/78	31	3-5
78/79	71	9-17
79/80	6	N/R
80/81	13	N/R
81/82	43	10-15
82/83	21	N/R
83/84	2	N/R
84/85	77	10-20
85/86	113	10-15
86/87	45	Vrb

* Criteria: Hours with air temp. $\leq 0^{\circ}C$, R.H $\leq$ 80% and wind speed $\geq$ 10 knots

\+ Mean of 6 Met sites in England

N/R Not reported, inferring low levels of damage.Vrb: varied considerably between Regions. (George, 1988)

Looking at the winters of 1985/86 and 1986/87 in greater detail, hours with below freezing air temperatures at Elmdon Airport, Birmingham, were analysed for the frequency of desiccating winds - see table 2

Table 2. Totals of Hours with Sub-Zero Air Temperatures : Elmdon (Dec-Feb)

R.H (%)	Windspeed (knots)					
	1985/86			1986/87		
	0-10	11-20	21-30	0-10	11-20	21-30
40-80	107	154	4	36	0	0
81-100	[illegible]	[illegible]	0	371	42	2

Although both winters were similar in that they recorded greater than normal totals of days with air frost, and at times both winters produced low temperatures ([illegible] in 85/86 and -13.2°C in 86/87 at Elmdon), there was a substantial difference in the number of frost hours with low humidities combined with moderate windspeeds (158 against zero hours). Thus, the assumption that low temperatures alone are less likely to cause widespread damage than are cold, desiccating winds is further vindicated.

2 METHOD

The layout of the plots* is given in figure 1. The treatments were:

2.1 Main Trial

a. Pots spaced - pots set on a grid pattern, approx 2 cm between pots.

b. Pot thick - pots packed together, touching and in a staggered pattern.

c. Edge board - as b but with a 15 cm surrounding board.

d. Peat plunge - as c but Agryl was placed under the bed and peat packed between the pots.

e. Slats - as c but with 1 cm thick boards, 7 cm wide, laid diagonally across pots to reduce air infiltration.

f. "Blakedown System" (BDS) - a 1 m high hooped tunnel lined with Agryl under an outer polythene skin.

* A technical description of the covering materials is given in the Annex.

g&h Treatments b and e were repeated inside a small Rokolene compound (approx 3 m x 3 m). However this was not erected until after the onset of the coldest spell of weather (16.1.87).

2.2 Supplementary Trial

A multi-tunnel of the same basic construction as f but with several inner coverings of [illegible] material fastened between sections to reduce internal [illegible] covered guard area was incorporated at either end.

The [illegible] were:

i. Agryl.

j. Small bubble polythene.

k. Large bubble polythene.

l. Thermofilm.

All the treatments were placed over gravel beds with pots contained 3 litres of compost with a mix of 75% peat, 10% capoflock* and 15% grit. Potting-on was completed by early summer in 1986, so the root system over winter can be considered as mature.

Two temperature probes were inserted in each treatment to a depth of 4 cm near to the centre of the root ball. One probe was in a edge pot with a southerly exposure while the other was situated in the 3rd pot in from the northern edge. Six samples of each species were included in each treatment, making 18 pots, with further plants of Berberis used to make the beds up to the size normally found at the nursery. Temperature recordings were all at 15 minute intervals and included air temperatures in a saucer screen and windspeeds at 2.2 m. A further saucer screen was set in the multi-tunnel to record an (unventilated) air temperature.

* Trade name for a basalt mineral wool.

3 RESULTS

3.1 Outside beds vs Blakedown System (main trial)

From the data files covering the whole study, certain key periods were examined in detail to illustrate important features.

3.1.1 Start of very cold, cloudy spell 9-13 January 1987

The Midlands was affected by a North Easterly air stream which became progressively colder. By the 10th 1400 GMT air temperatures fell below 0°C and the steady fall continued reaching -13°C during the night of 12/13th. Winds on site were light to moderate, not exceeding 5 m/s: see figure 2.

In general compost temperatures remained at or around 0°C until the 11th at 1200 GMT, ie not reacting to the preceding cold night when air temperatures fell to -6.6°C. Thereafter there was a steady fall; the daily minimum values are shown in table 1.

Table 1 Minimum Compost Temperatures (inner pots) °C

	11 Jan	12 Jan	13 Jan
Pot spaced	-0.4	-6.6	-10.0
Pot thick	-0.8	-5.2	-9.4
Edge board	-0.8	-5.0	-9.2
Peat plunge	-1.8	-3.4	-6.2
Slats	-0.2	-3.2	-8.0
BDS	-0.2	-0.4	-0.6
Pot thick*	-1.2	-4.4	-9.2
Slats*	-0.4	-4.0	-7.8
Ambient air	-6.6	-8.6	-13
Mean wind m/s	2.7	1.4	3.1

* After 16 Jan, these beds were sheltered by a compound of 1 m high Rocolene.

Conclusion:

i. Compost temperatures prior to freezing are less reactive to low ambient temperatures.

ii. The peat plunge was initially coldest, but in more severe conditions it maintained a temperature higher than comparable treatments.

iii. The BDS tunnel was clearly the most effective treatment.

iv. Root temperatures of -6 to -10°C on the 13th were sufficiently low to kill or severely affect several species of hardy nursery stock. (See Studer et. al, 1978).

v. The pot spaced exposure recorded the lowest temperatures, but they were not substantially lower than several other treatments.

3.1.2 Snow, drifting and rising temperatures 13-16 June

Snow fell on the 13th and 14th and in winds reaching 10 m/s on the 14th there was considerable drifting. The outside beds were not evenly covered by snow. The temperature profiles are shown in figure 3. The 14th will have been stressful for top growth as the air temperature was still -4 to -5 °C during the period of the strongest winds. However, relative humidity levels were quite high (85 to 95% at Elmdon) so desiccation of top growth was not manifest.

Table 2 Minimum Compost Temperatures (inner pots) °C

	14 Jan	15 Jan	16 Jan
Pot spaced	-6.8	-1.8	-1.0
Pot thick	-6.8	-3.0	-1.8
Edge board	-6.6	-2.2+	-1.2+
Peat plunge	-3.4	-1.2+	-0.8
Slats	-6.2	-2.4	-1.4
BDS	-0.4	-0.4	-0.4
Pot thick*	-6.4	-3.4	-1.8
Slats*	-5.2	-2.2	-1.4
Ambient air	-5.6	-5.0	-0.6
Mean wind (m/s)	5.9	3.8	3.5

* Rokolene compound erected on 16 Jan.

+ Treatments with deepest snow cover.

Conclusions:

i. Pot spaced reacted most quickly to warmer air temperatures.

ii. BDS only had snow round edge of tunnel and was little affected.

iii. The snow cover greatly reduced the differences in compost temperatures between the covered and uncovered treatments.

3.1.3 Clear, cold radiation nights with light winds 29 Jan - 1 Feb.

After the snow had melted there was a milder, cloudy spell with ambient temperatures in the range 1 to 6°C and light winds. Clearer weather from the 28th produced daytime air temperatures of 4 to 5°C but by night these fell to -3 to -8°C. The corresponding compost temperatures are given in table 3 and illustrated in figure 4.

Table 3 Minimum Compost Temperatures (inner pots) °C

	30 Jan	31 Jan	1 Feb
Pot spaced	0.0	-0.6	-2.0
Pot thick	-0.6	-1.6	-2.4
Edge board	-0.2	-1.8	-2.2
Peat plunge	-1.2	-3.4	-3.6
Slats	-0.6	-1.2	-1.2
BDS	0.2	-0.2	-0.2
Rocolene	-0.8	-2.2	-2.6
Roc and slats	-0.8	-1.8	-2.2
Ambient air	-3.0	-8.0	-5.2
Mean wind (m/s)	1.5	0.7	0.6

Conclusions:

i. Again, initially low ambient temperatures were not reflected in lower compost temperatures.

ii. On the coldest night the peat plunge treatment produced the lowest reading.

iii. BDS minimum temperatures were higher than any other treatment.

iv. From fig 4 BDS daytime maxima were up to 10°C (inner pots).

v. The pot thick treatment was slightly, but consistently colder than the pot-spaced treatment.

3.2 Multi-Covering Tunnel (Supplementary Trial)

Pots containing Prunus lusitanica and Berberis stenophylla were transferred from elsewhere in the nursery on the 12th Jan. Their initial compost temperatures were -6 to -10°C and they did not achieve parity with the BDS tunnel until 21st Jan. All the coverings were not delivered until early January.

The results from this section of the trial were generally unsatisfactory, primarily because it was decided to include all the different inner covering materials under a single outer polythene skin. Accordingly it cannot be stated with any confidence that we avoided interference between adjoining coverings.

However, certain conclusions can be drawn from the results which will help in planning similar future studies.

3.2.1 Comparison of compost temperatures: minima

The daily minimum compost temperatures were similar (i) between the different coverings and (ii) between the inner and outer pots: see table 4 and figure 5.

Table 4 Minimum Compost Temperatures °C

		30 Jan	31 Jan	1 Feb
Agryl	inner pot	-0.8	-0.8	-0.6
	outer pot	-0.4	-0.4	-0.4
Small Bubble	inner pot	-0.2	-0.2	-0.4
	outer pot	0.0	-0.2	-1.4
Large Bubble	inner pot	-0.2	-0.2	-0.2
	outer pot	-0.2	-0.2	-0.2
Thermofilm	inner pot	-0.2	-0.2	-0.2
	outer pot	0.0	0.0	0.0
BDS tunnel (Agryl)	inner pot	0.2	-0.2	-0.2
	outer pot	-0.4	-0.6	-0.6

3.2.2 Comparison of Compost Temperatures: Maxima

While the daily minima showed only small differences between materials and exposures, the daily maxima were considerably different. This is attributed to the ability of the coverings to reflect and/or diffuse incoming solar radiation and thus suppress the daytime temperature increase in the compost. Figure 5 illustrates this feature, but note that the Agryl covering illustrated was taken from the single, small tunnel in preference to the readings from the multi-tunnel, as there was some shading of the Agryl section by the Rokolene compound (see figure 1).

Both the Agryl and Thermofilm coverings produce a large diurnal variation in compost temperature (exceeding that of the air temperature in the tunnel), while pots under the large and small bubble polythene coverings showed a very small diurnal variation, even in bright weather. The pots exposed to the south side of the tunnel were more strongly influenced than the inner pots.

There are recognised dangers in permitting high daytime temperatures, namely

i. The tunnel air can be above freezing while the compost remains below freezing. A resultant transpiration demand may not be met as the compost moisture remains locked as ice. Cellular disruption leading to desiccation may result. (Sakai, 1970).

ii. High daytime temperatures will advance plant development. The fresh growth is very susceptible to direct frost damage in a subsequent cold spell, especially after the removal of the covers.

Neither of these effects were encountered during this study.

3.3 Damage Assessment of Plant Material

The tunnel covering was removed on 4 March 1987 and, following subsequent slight to moderate frosts, the plant assessment was completed on 25 March. Unfortunately the uncovered treatments were inadvertently sold prior to the assessment. Only the plants from the Rokolene compound remained, but they experienced very similar conditions to the outside beds thus they were taken as representative of the missing treatments: see table 5.

The Prunus lusitanica were not assessed due to waterlogging damage.

Conclusions:

i. The Rosemarinus being the least hardy showed marked differences in both top growth and root survival, compared to the other treatments.

ii. Berberis survived best in the BDS but the Spiraea showed a reverse effect.

Table 5 Plant Assessment on 25th March 1987

TREATMENT	SUBJECT	MEAN QUALITY (SCALE 0-5)* TOP GROWTH	ROOTS	OBSERVATIONS
Blakedown Tunnel	Berberis	3.7	4.1	
	Spiraea snowmound	+	2.8	
	Rosemarinus officinalis	4.0	3.3	
Rocalene + Slats	Berberis	3.9	3.5	
	Spiraea snowmound	+	3.5	
	Rosemarinus officinalis	2.7	2.2	Have not broken as early and looking slightly brown. Some snow damage. Compost a lot wetter. Many brown/discoloured roots.
Rocalene & Pot thick	Berberis	3.8	3.4	
	Spiraea snowmound	+	3.4	
	Rosemarinus officinalis	1.7	1.4	Compost waterlogged. Much root death.

* Mean quality on a scale of 0-5 (5 best, 0 worst).

+ Top growth quality of Spiraea was not assessed because there were 2 clones, and the Spiraea in the tunnel was so much more advanced in spring growth.

Photographs taken on 4th March of the outside plots and BDS showed the plants from under the BDS to be considerably more advanced. For example the Spiraea was well in leaf and some plants had their first open flowers, while in the pot thick treatment the leaf buds had hardly begun to swell. Subjectively the BDS produced material two weeks earlier than the other plots.

4 DISCUSSION

Several major points have emerged from this study:

i. Winter kill. Damage to nursery stock in 1986/87 was slight and was most likely caused by low compost temperatures on 12/13 Jan, rather than through desiccation effects.

ii. Freezing compost. Because the severity of frozen compost varied dramatically between covered and protected treatments, and because during isolated cold nights it was seen that compost temperatures responded only

marginally to low air temperatures, it is worth considering the processes of heat transfer in greater detail.

If the total overnight heat loss from an unprotected pots is H, and the total heat gain, (mainly through heat conduction from the underlying bed) is G, then for a stable compost temperature on a cold night H = G (eg figure 2 for 11 January).

During an extended period of freezing weather, the amount of heat supplied by the bed will decrease, while the rate of heat loss may remain approx constant thus causing compost temperatures to fall.

On reaching the freezing point of the compost (C. - 0.6°C) there will be a temporary heat gain through the release of latent heat. However, the thermal conductivity, k, of the compost will increase (see below) causing the rate of heat loss to increase, allowing compost temperatures to fall more quickly, (eg figure 2 for 12 January).

Under a covered tunnel, the accumulated effects of enhanced daytime temperatures will warm the pots and the underlying beds to temperatures exceeding those in unprotected beds. Thus during a cold spell, not only will there be a greater source of heat from the underlying bed, but due to absorption and reflection, the rate of heat lost from the structure will be reduced.

The net effect will be the maintenance of stable compost temperatures over a longer period (eg figures 2 and 3, tunnel temperatures 11-14 January).

By increasing the rate of heat transfer from the bed to the pot, possibly by using sand beds rather than gravel beds, a higher compost temperature should be possible.

iii. Thermal conductivity of compost. Once a compost was frozen it reacted much more quickly to changing ambient temperatures. This explains the lack of response of compost temperatures on 30/31 Jan compared to the 1st February, and the sudden drop of compost temperatures on 11 Jan after the air temperature had been well below freezing for the previous 24 hours.

The reason for this can be found by looking at typical composts which contain 65% water, 10% air and 25% solids, by volume. The rate of compost cooling depends on the thermal conductivity (k) of the compost. The k value for water is 0.6 w/m/K while for ice it is 2.2 w/m/K, and air is 0.025 w/m/K. Therefore on freezing the air space will be reduced and the ice component of the compost will have a greater ability to conduct heat, thus allowing more rapid cooling to nearer ambient temperatures.

iv. Pot thick vs pot spaced. Previous reports on compost temperature recordings indicate that plant spaced pot thick can have a 5°C advantage over pots set apart (George, 1986). Further, compost in square pots packed close together "achieved substantially higher viability ratings than plants in round containers after freezing" (Rohsler et al, 1983). In light of this it is somewhat perverse that no similar large temperature differences were recorded in this trial. During the single crucial period of cold weather, 12/13 Jan, plants placed pot thick had a small (0.6 to 1.4°C) temperature advantage: frequently the opposite was true. One possible explanation is that in this study compost temperatures were measured towards the centre of the root ball. Compost temperatures if recorded near to the outer edge of the pot, and among the denser area of younger and less hardy roots, may have revealed greater temperature differences between pots placed thickly and thinly. This will be investigated in a further study.

v. Slats and peat plunge. Both these treatments offered a measure of protection, but due to the labour involved in arranging the plots the techniques are unlikely to be accepted commercially. The results from the peat plunge were peculiar in that under certain conditions (ie 1st Feb) this treatment produced the lowest compost temperature while during even colder weather (ie 13th Jan) it produced one of the highest temperatures. This apparent paradox is explained from figure 4 where it can be seen that early on 29th Jan all uncovered treatments showed similar temperatures but during the following night the peat plunge temperature fell to -0.6°C while the others were between 0.0°C and -0.4°C. It is a fair assumption that only the peat plunge compost froze (thereby increasing its thermal conductivity) and thus became more reactive to ambient air temperatures of -5 to -8°C on the following

nights. This highlights the importance of the state of the compost while the temperature is between -0.4 and -1.0°C ie the point at which it freezes.

The slats arrangement is similar to the insulated pallets studied by Mahoney et al (1983).

vi. Rokolene compound. This was not erected early enough to be of much significance to this trial. In any case windspeed recordings rather than temperature would have been more appropriate as the sole purpose was to reduce the number of hours when desiccating winds could have affected the plants. Of the temperature recordings given in table 3 it can be seen that the shading caused by the rokolene screen produced lower night time (and lower daytime) compost temperatures than did the corresponding treatments not surrounded by a screen. Thus screening may be detrimental to temperature protection but beneficial for wind protection.

vii. Agryl lined tunnel. At its coldest, the inner pots under the low tunnel fell to -0.6°C. Thus it is likely that many of the pots avoided freezing throughout the winter (but only just). With the marked rise in daytime temperatures during bright weather it is probable that both root and top growth continued during the winter and this in turn enhanced the subsequent assessment on 25th March. Although relative humidity and wind speed were not measured under the tunnel we can assume that RHs would have been higher than ambient, and air speed certainly lower - thus affording substantial protection against cold, desiccating winds.

viii. Multi-tunnel. In this trial little difference in minimum temperatures were recorded. This may have been due to interference between the coverings under the single outer polythene skin. However, it is clear that daytime temperatures were strongly affected and the ability of some materials to limit the rise in compost temperature by day is considered advantageous. It should be possible to reproduce this effect with cheaper materials, eg. an opaque milky polythene (Wiest et al 1976).

ix. Plant Assessment. The Berberis stenophylla and Rosemarinus officinalis from under the Agryl lined tunnel clearly overwintered more successfully than those from the uncovered treatments. Assessment of Spiraea cv Snowmound was complicated by having two different clones which could not be directly compared, but from the photographic evidence the plants from under the tunnel were clearly the more advanced. The root assessment indicated that the healthier root systems were from the outside beds.

A possible explanation is that the covered pots experienced a greater transpiration demand from the more advanced plants, thus drying out the compost and damaging the root system. (It was noted that the pots from the covered treatments were considerably lighter than those from the outside beds).

5 GENERAL CONCLUSIONS

i. The winter of 1986/87 was not particularly damaging to nursery stock.

ii. Covered treatments showed a clear and consistent advantage over uncovered treatments.

iii. Minimum compost temperatures in all covered treatments were similar.

iv. Maximum compost temperatures varied greatly between covered treatments.

v. During the coldest weather the peat plunge treatment gave most protection (uncovered beds) followed by the slats.

vi. There were only small and inconsistent differences between compost temperatures in the pot thick and pot spaced treatments.

vii. The advantage of reduced wind speed in the Rokolene compound was partially offset by lower compost temperatures caused by shading.

viii Snow cover insulated the compost from low ambient temperatures and thus afforded considerable protection to the roots.

ix. Frozen compost was more reactive to changing ambient temperatures than was unfrozen compost.

x. Root assessments between trials showed more variation than did top growth.

xi. Roots were probably damaged due to cold temperatures on 12/13 Jan 1987.

xii. Dry compost from the covered trials may have adversely affected the root systems.

xiii There were no gales during the study period.

Any comments or suggestions should be referred to the author

Post Script: This memorandum was compiled from a confidential ADAS report first issued in April 1987.

Acknowledgements

Thanks to J Ward, ADAS Worcester, in helping to set up and execute the study and to D Fryer for completing the plant assessments.

Mr D Crummy, Nursery Manager at Blakedowns, proved invaluable with his informed opinions, ready wit and frequent assistance during the spells of weather which I welcomed but he did not!

Blakedown Nurseries kindly supplied all the covering materials and plants used in the trial.

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Annex Materials used in Trial

Covering Material	**Type**	**Cost p/m^2**	**Manufacturer**	**Features**
Clear polythene	38 micron	8.2	British Visqueen	-
Agryl P.17	Bonded Polypropylene 17g/m^2	11.3	-	-
Small bubble	Bubble polythene		-	U.V. stabilised on clear film
Large bubble	Bubble polythene		-	U.V. stabilised twin laminate
Thermofilm IR	Polythene film	33	Polyon-Barkai (Israel)	U.V. stabilised copolymer anticondensate
Windbreak				
Rokolene	High density polyethylene	-	-	50% porous
Tunnel Construction (size 2.1 x 3.7 x 1m high)				
1m hoops	Aluminium	-	Karrilea	-

No endorsement is intended for any product used in this trial.

BLAKEDOWN NURSERIES TRIAL AREA 1987

Figure 1

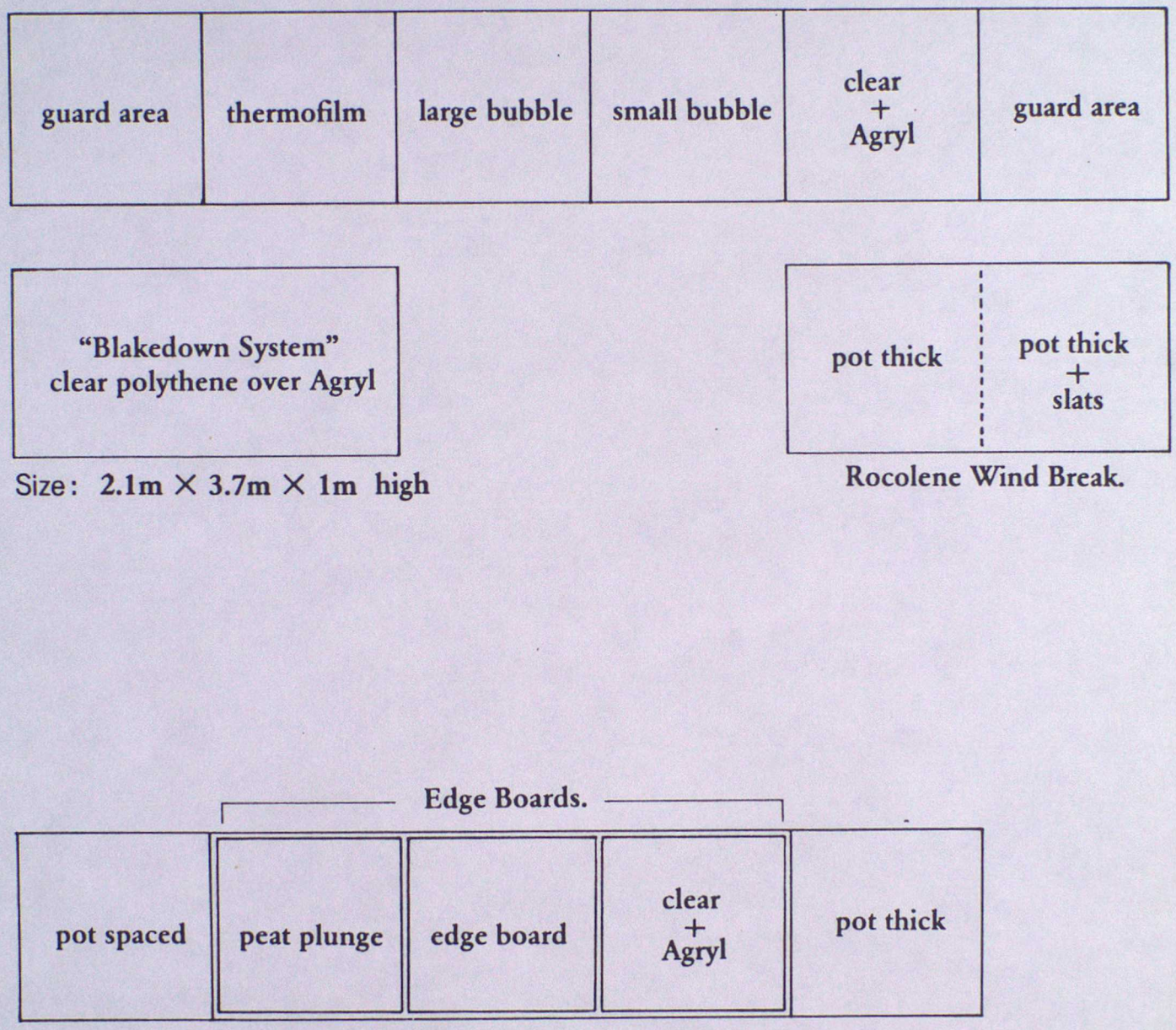
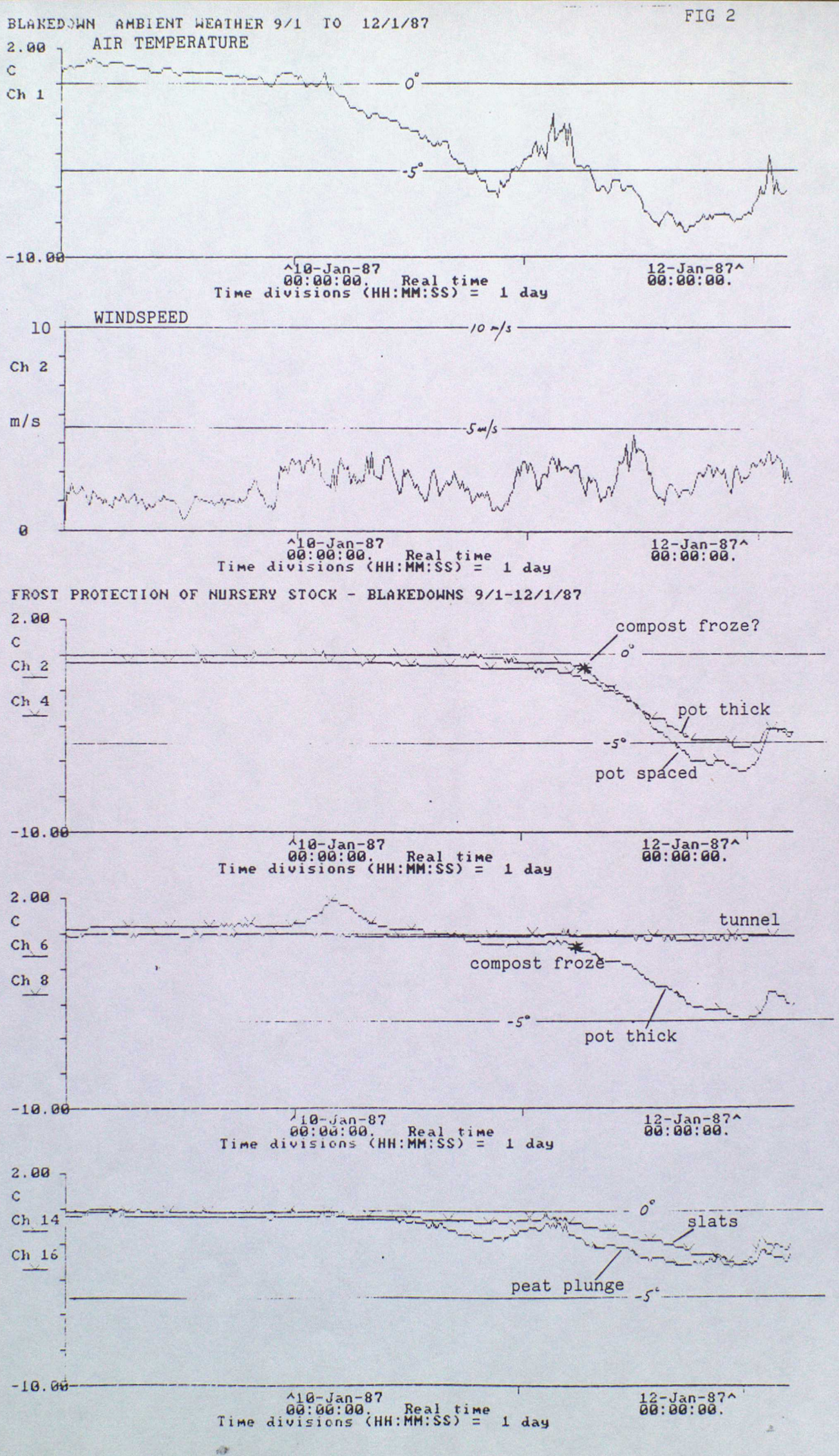
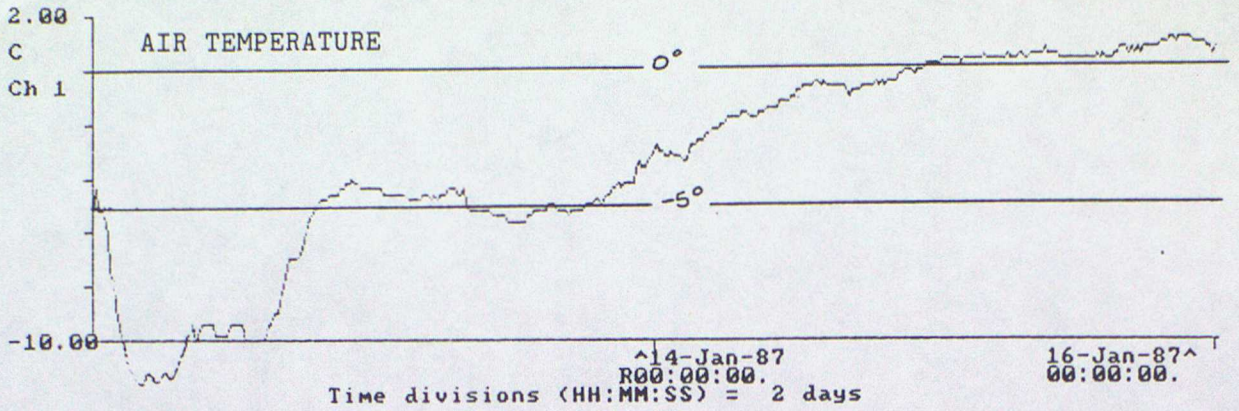


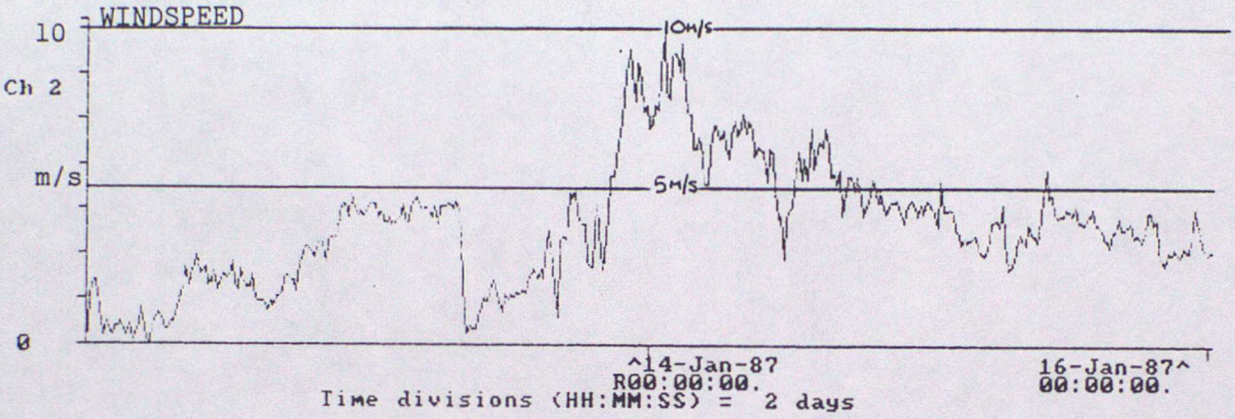
FIG 2


BLAKEDOWN AMBIENT WEATHER 9/1 TO 12/1/87
AIR TEMPERATURE
2.00
C
Ch 1
0°
-5°
-10.00
^10-Jan-87
00:00:00. Real time
12-Jan-87^
00:00:00.
Time divisions (HH:MM:SS) = 1 day
WINDSPEED
10
Ch 2
m/s
10 m/s
5 m/s
0
^10-Jan-87
00:00:00. Real time
12-Jan-87^
00:00:00.
Time divisions (HH:MM:SS) = 1 day
FROST PROTECTION OF NURSERY STOCK - BLAKEDOWNS 9/1-12/1/87
2.00
C
Ch 2
Ch 4
compost froze?
0°
pot thick
-5°
pot spaced
-10.00
^10-Jan-87
00:00:00. Real time
12-Jan-87^
00:00:00.
Time divisions (HH:MM:SS) = 1 day
2.00
C
Ch 6
Ch 8
tunnel
compost froze
-5°
pot thick
-10.00
^10-Jan-87
00:00:00. Real time
12-Jan-87^
00:00:00.
Time divisions (HH:MM:SS) = 1 day
2.00
C
Ch 14
Ch 16
0°
slats
peat plunge
-5°
-10.00
^10-Jan-87
00:00:00. Real time
12-Jan-87^
00:00:00.
Time divisions (HH:MM:SS) = 1 day

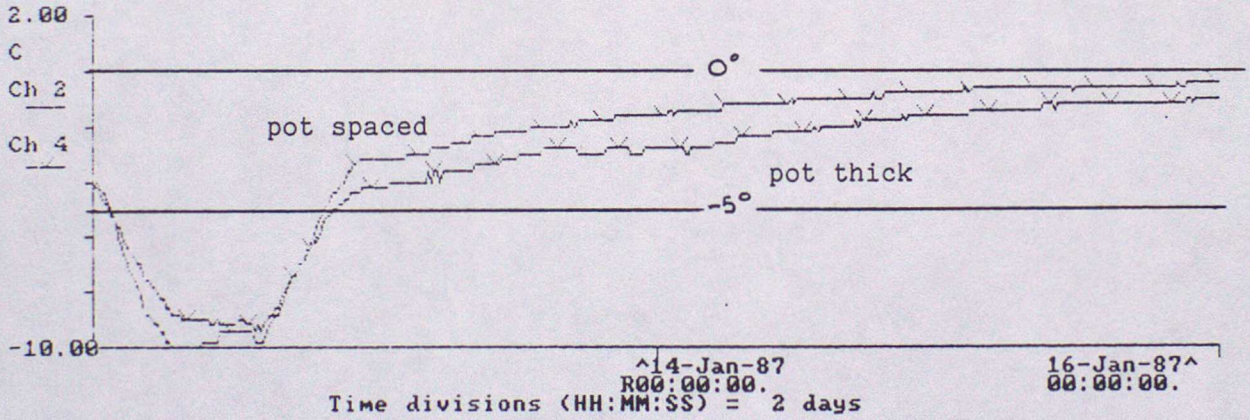
AMBIENT WEATHER AT BLAKEDOWNS 12/1 - 16/1/87

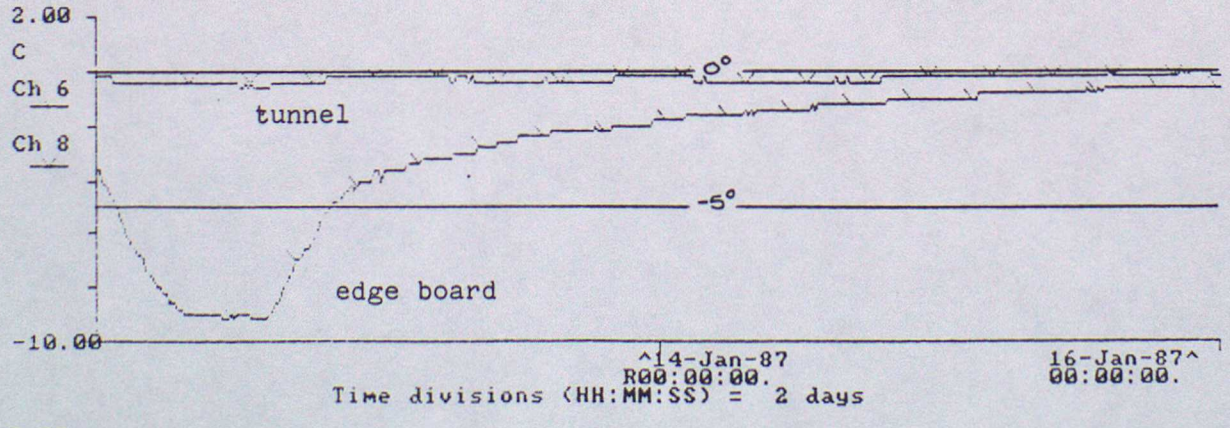
FIG 3

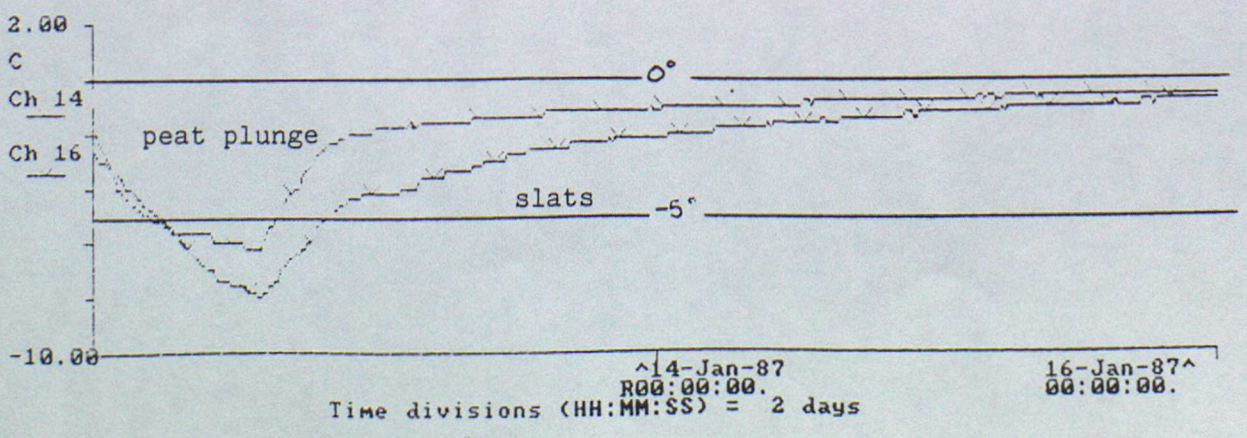




BLAKEDOWNS 12/1 - 16/1/87 IN POTS

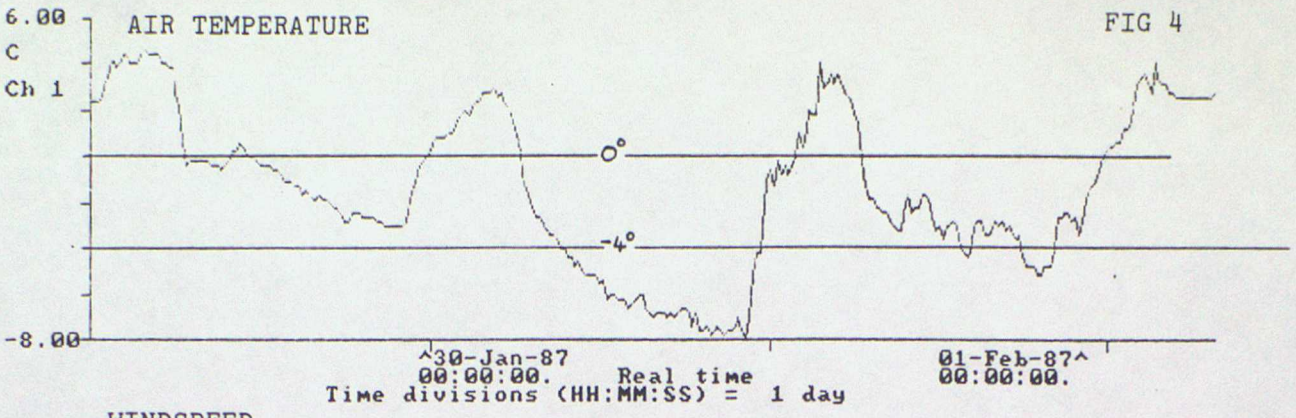


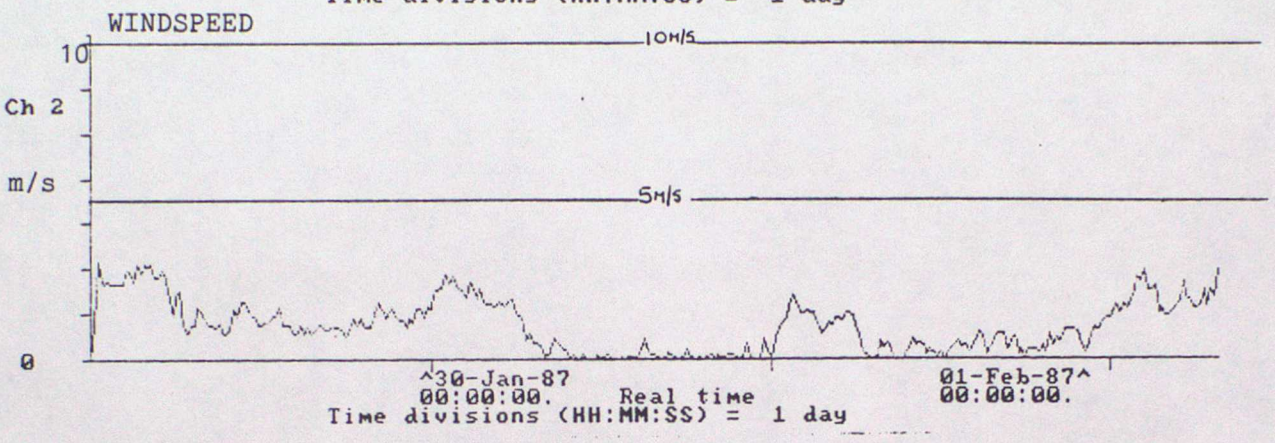




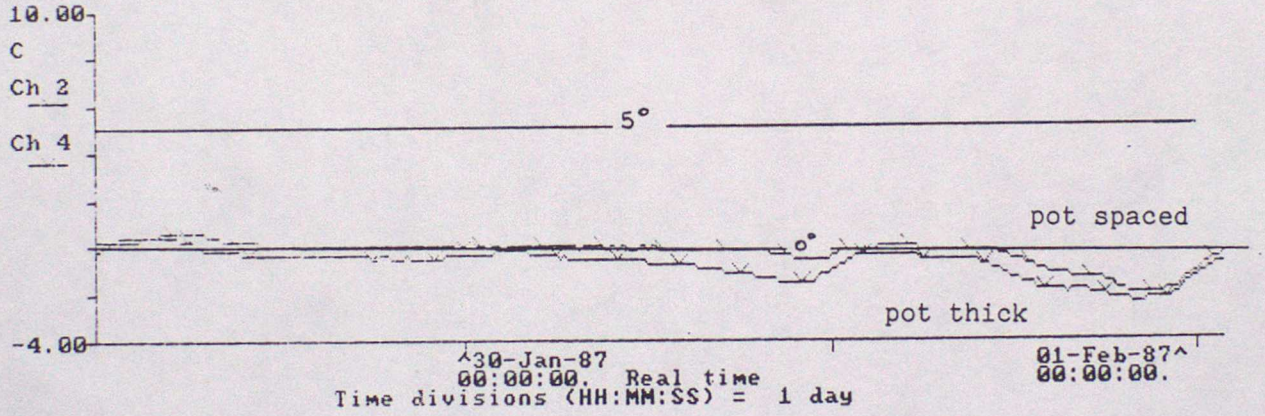
AMBIENT WEATHER AT BLAKEDOWN 29/1 - 1/2/87

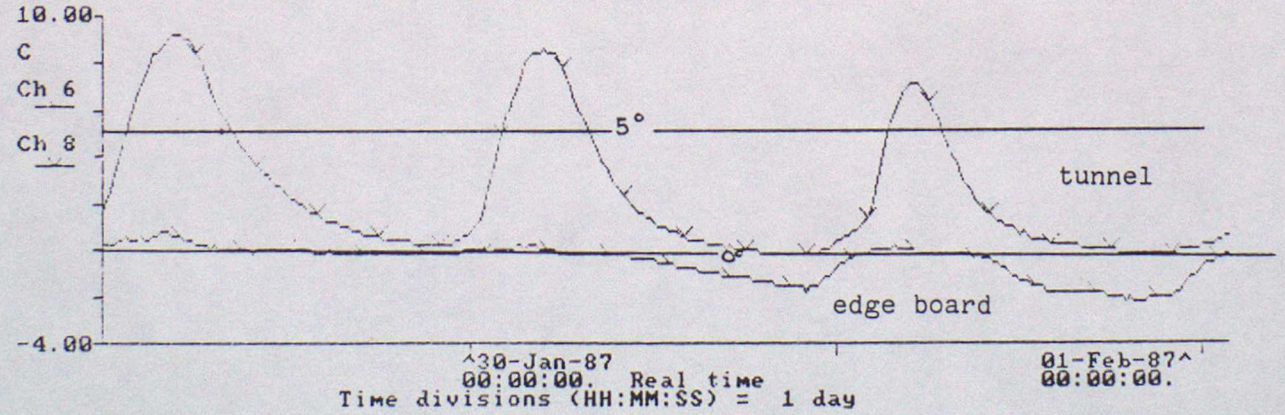
FIG 4

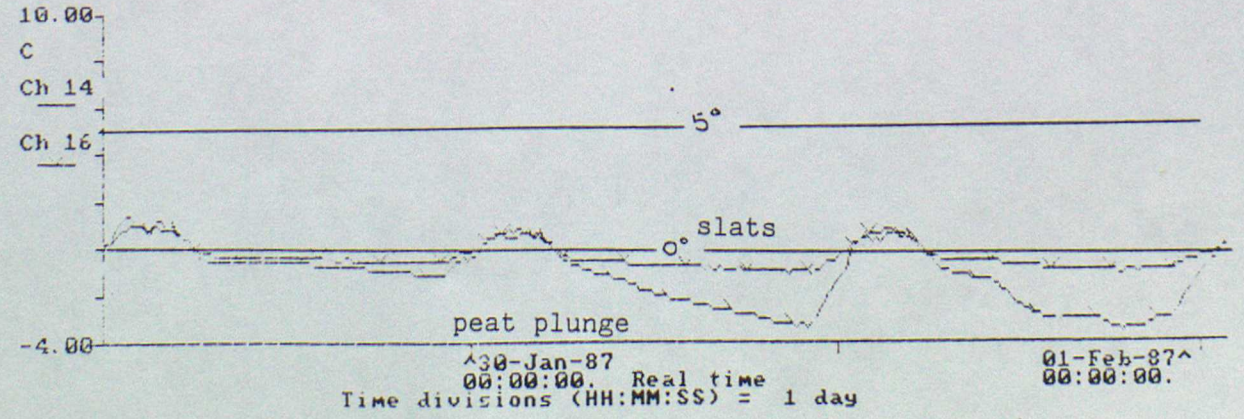




BLAKEDOWN POT TEMPERATURES 29/1 - /2/87

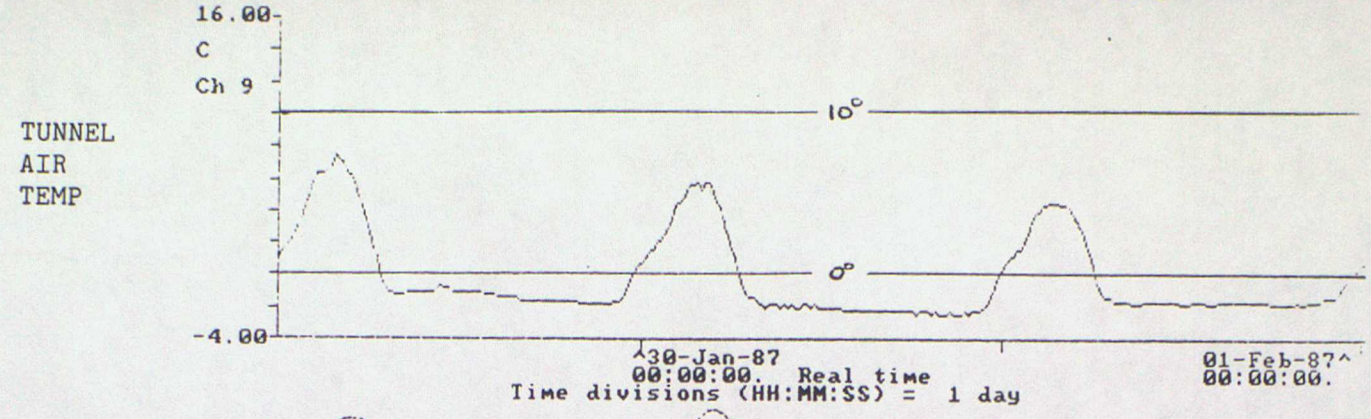




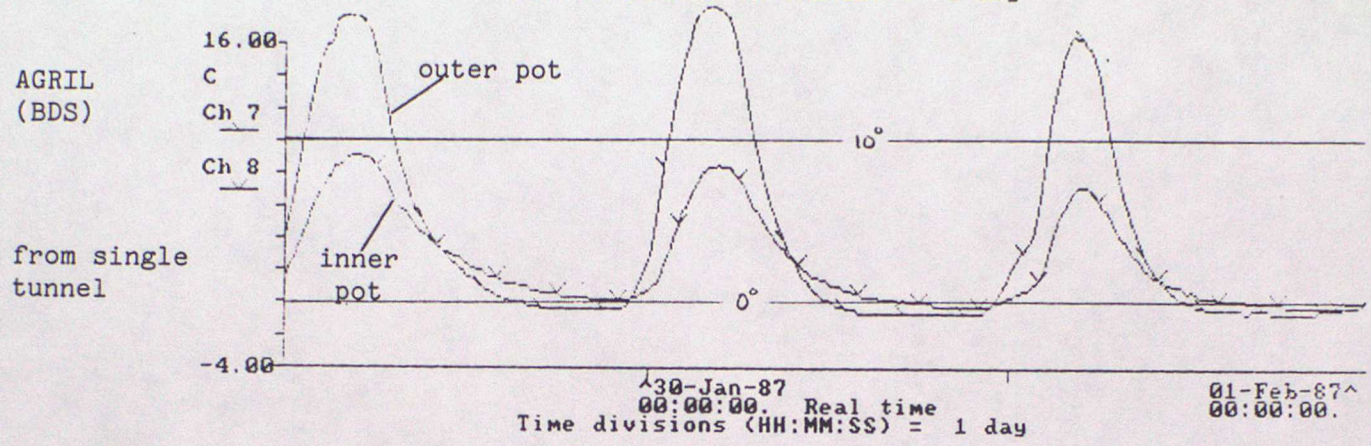


BLAKEDOWN TUNNEL TEMPERATURES 29/1 - 1/2/87

FIG 5

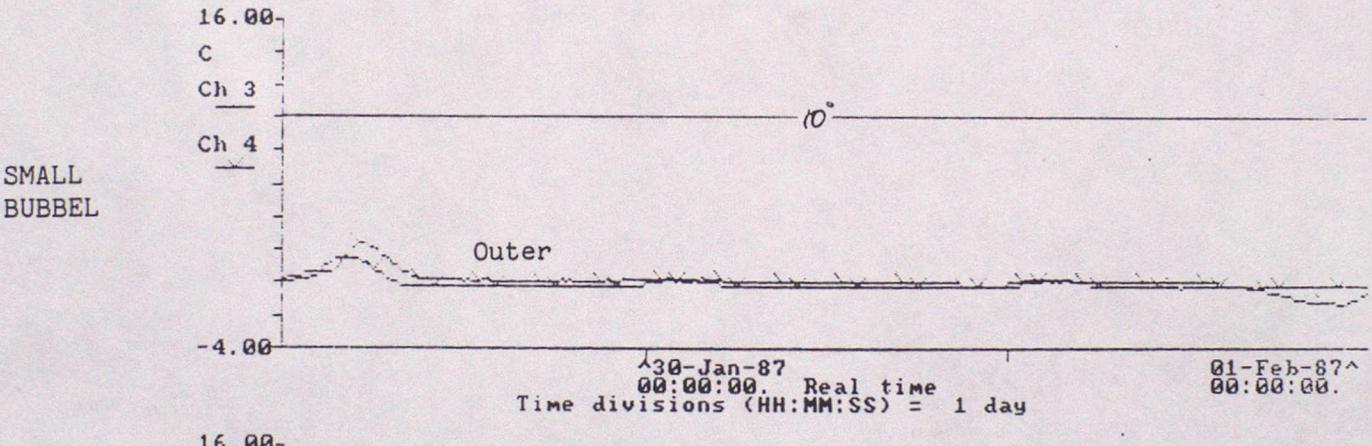


TUNNEL AIR TEMP

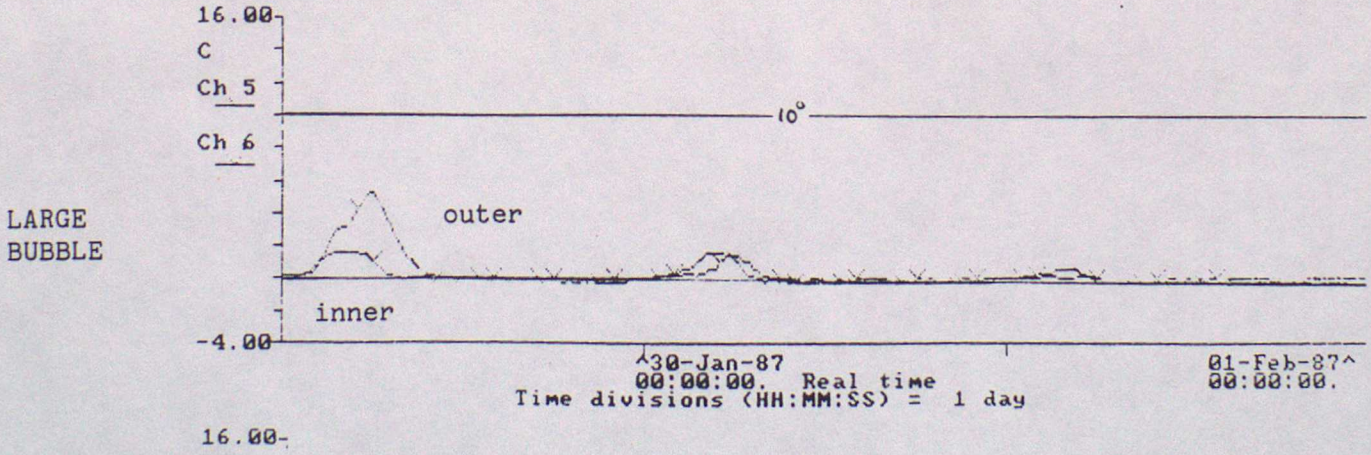


AGRIL (BDS)

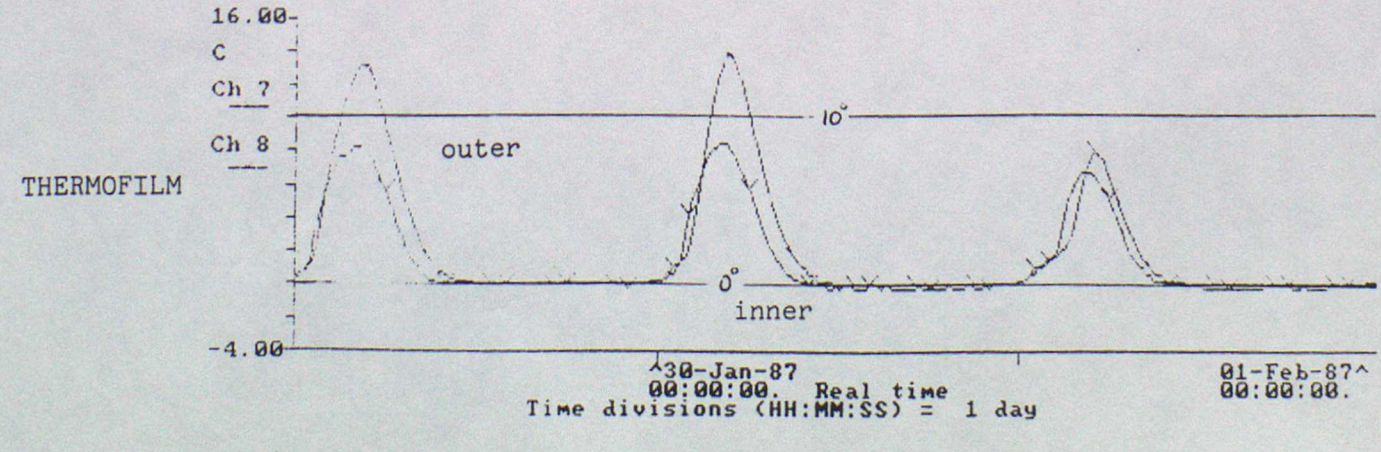
from single tunnel



SMALL BUBBEL



LARGE BUBBLE



THERMOFILM